J Raptor Res. 32(4):290–296

AN INFRARED VIDEO CAMERA SYSTEM FOR MONITORING DIURNAL AND NOCTURNAL RAPTORS

David K. Delaney[1] and Teryl G. Grubb
USDA Forest Service, Rocky Mountain Research Station, 2500 S. Pine Knoll Dr., Flagstaff, AZ 86001-6381 U.S.A.

David K. Garcelon
Institute for Wildlife Studies, P.O. Box 1104, Arcata, CA 95518 U.S.A.

Abstract.—A black and white, circuit-board video camera system with night vision was designed to monitor Mexican Spotted Owl (*Strix occidentalis lucida*) behavior. A 0.5-Lux infrared camera equipped with a 3.3 mm lens permitted vision up to 3 m in total darkness with the aid of six infrared light-emitting diodes (LEDs). To extend nighttime visibility at selected sites to approximately 6 m, we constructed a supplemental 9-LED infrared light source. Industrial-grade video recorders provided up to 24-hr coverage per VHS tape. Cameras averaged 6.9 m from nests (range 3.0–10.3 m). Mean camera installation time was 42 min (range 28–71 min). Between 25 April–3 July 1996, approximately 820 hr of video effort (76 hr for equipment assembly, 14 hr for camera placement, 230 hr for maintaining tapes and batteries, and 500 hr for subsequent video analysis) provided 2655 hr of usable video coverage (149 tapes) at 20 nest sites, a return ratio of nearly 3.2:1 hr of coverage for each hour invested. Comparable detail, quality, or quantity of behavioral data would not have been possible through direct observation. This video system could have a wide application in other raptor behavior studies, especially for determining the effects of human activities.

Key Words: *behavior; diurnal activity; infrared photography; Mexican Spotted Owl; nocturnal activity;* Strix occidentalis lucida; *surveillance; video camera.*

Un sistema de video cámara infrarojo para el monitoreo de aves rapaces diurnas y nocturnes

Resumen.—Un sistema de video cámara en blanco y negro con visión nocturna fué diseñado para el monitoreo del comportamiento de *Strix occidentalis lucida.* Una cámara de 0.5 Lux equipada con un lente de 3 mm permitió una visión de hasta 3 m en la obscuridad total con la ayuda de una luz infraroja de seis diodos. Con el fin de extender la visibilidad nocturna a 6 m en sitios seleccionados, construimos una fuente de luz infraroja suplementaria de 9 diodos. Con video grabadoras industriales cubrimos períodos de 24 horas en cintas de VHS. La distancia promedio de los nidos fue de 6.9 m (rango = 3.0–10.3 m). La media del tiempo de instalación de la cámara fue de 34 min (rango = 28–71 min). Entre el 25 de abril–3 de julio de 1996, 820 hr de video fueron registradas (76 hr para el ensamblaje del equipo, 14 hr para la ubicación de la cámara, 230 hr para el mantenimiento de cintas y baterías y 500 hr para el análisis de video) 2655 hr de cobertura de video (149 cintas) en 20 nidos, una tasa de retorno de cerca de 3.2:1 hr de cobertura por cada hora invertida. El detalle, la calidad o cantidad de datos de comportamiento no hubiera podido ser obtenida a través de observaciones directas. Este sistema de video puede tener una aplicación amplia en estudios de comportamiento de otras aves rapaces especialmente con el fin de determiner los efectos de actividades humanas.

[Traducción de César Márquez]

Collecting baseline behavioral information on animals from field observations is an important prerequisite to determining and mitigating the effects of human activities. To compare animal behavior between manipulated and nonmanipulated sites or periods, it is often necessary to make simultaneous observations at more than one location and for extended periods of time. For studying owls, the ability to monitor nocturnal behavior is also critical. Recording wildlife activity with remotely operated or automatic cameras has a long history (Dodge and Snyder 1960, Osterberg 1962, Cowardin and Ashe 1965, Patton et al. 1972). Techniques include time-lapse, super-8 movie cameras (Grubb 1983), conventional video cameras (Nye

---

[1] Present address: U.S. Army Construction Engineering Research Laboratories, P.O. Box 9005, Champaign, IL 61826 U.S.A.

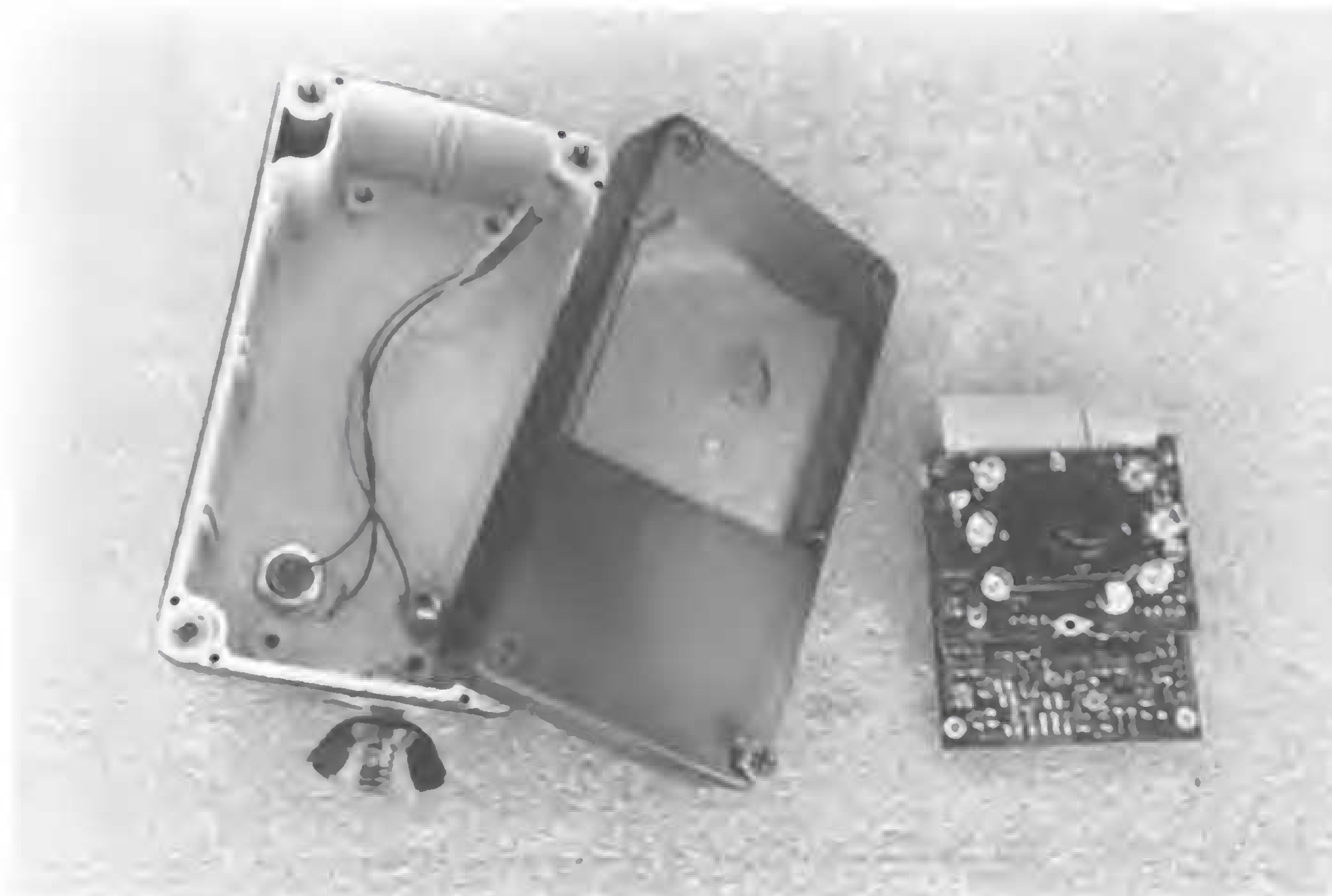

Figure 1. Miniature circuit-board video camera with weatherproof, plastic switch-box painted black (except for the lens and LED area) and wired for video and power connections.

1983, Kristan et al. 1996), miniature video-board cameras (Proudfoot 1996), 110 instamatic cameras (Jones and Raphael 1993), 35-mm infrared-aided cameras (Hernandez et al. 1997), and the most common approach, 35-mm, flash-aided photography (Major 1991, Kucera and Barrett 1993, Browder et al. 1995, Danielson et al. 1996).

During a recent study on the effects of helicopter and chain-saw noise on nesting Mexican Spotted Owls (*Strix occidentalis lucida*; Delaney et al. 1999a), we chose video surveillance as the primary means of recording owl behavior and responses to manipulations at nest sites because it did not require capturing or handling owls for radiotelemetry, could be operated remotely with minimal disturbance to the owls, was silent with no moving parts, provided both diurnal and nocturnal recording capability, and facilitated real time, behavioral analyses *a posteriori*. However, to meet the unique requirements of unobtrusively recording continuous behavior of this primarily nocturnal species, we had to design a camera system that was small and easily mounted, functional in both daylight and darkness, and sufficient for monitoring owl nesting activity and prey deliveries. This paper describes the design, construction, and deployment of this essentially noninvasive, infrared video camera system for monitoring 24-hr activity at Mexican Spotted Owl nest sites.

METHODS

We used Marshall[2] black and white, charge-coupled device (CCD), circuit-board video cameras (Marshall Electronics, Culver City, CA U.S.A.; Fig. 1). The solid state, 12-volt, circuit-board cameras came equipped with 3.3-mm lenses, which we replaced in most cases with an optional 12.0-mm lens. A fully automatic electronic shutter compensated between bright daylight and nighttime conditions. The camera provided a minimum of 380 lines of resolution and with 0.5-Lux, permitted vision up to 3 m in total darkness with the aid of six infrared light-emitting diodes (LEDs; Figs. 1, 2A). To approximately double night vision capabilities (i.e., to monitor nests up to 6 m away), we designed supplemental infrared, 9-LED (Tandy Corp., Ft. Worth, TX U.S.A.), light sources on 5-cm (2-inch) diameter circuit boards mounted in PVC-pipe end caps sealed with plexiglass (Fig. 2B). Each of these lights was then attached to a 2-m piece of lightweight aluminum screen molding that facilitated independent mounting in camera trees closer to the nests under observation. Cameras were mounted in waterproof, heavy-gauge plastic switch-boxes with transparent covers (11.5 × 6.4 × 5.5 cm; Newark Electronics, Chicago, IL U.S.A.) which, ex-

[2] Use of trade names does not imply endorsement by the USDA Forest Service, Rocky Mountain Research Station, or Institute for Wildlife Studies to the exclusion of other potentially suitable products.

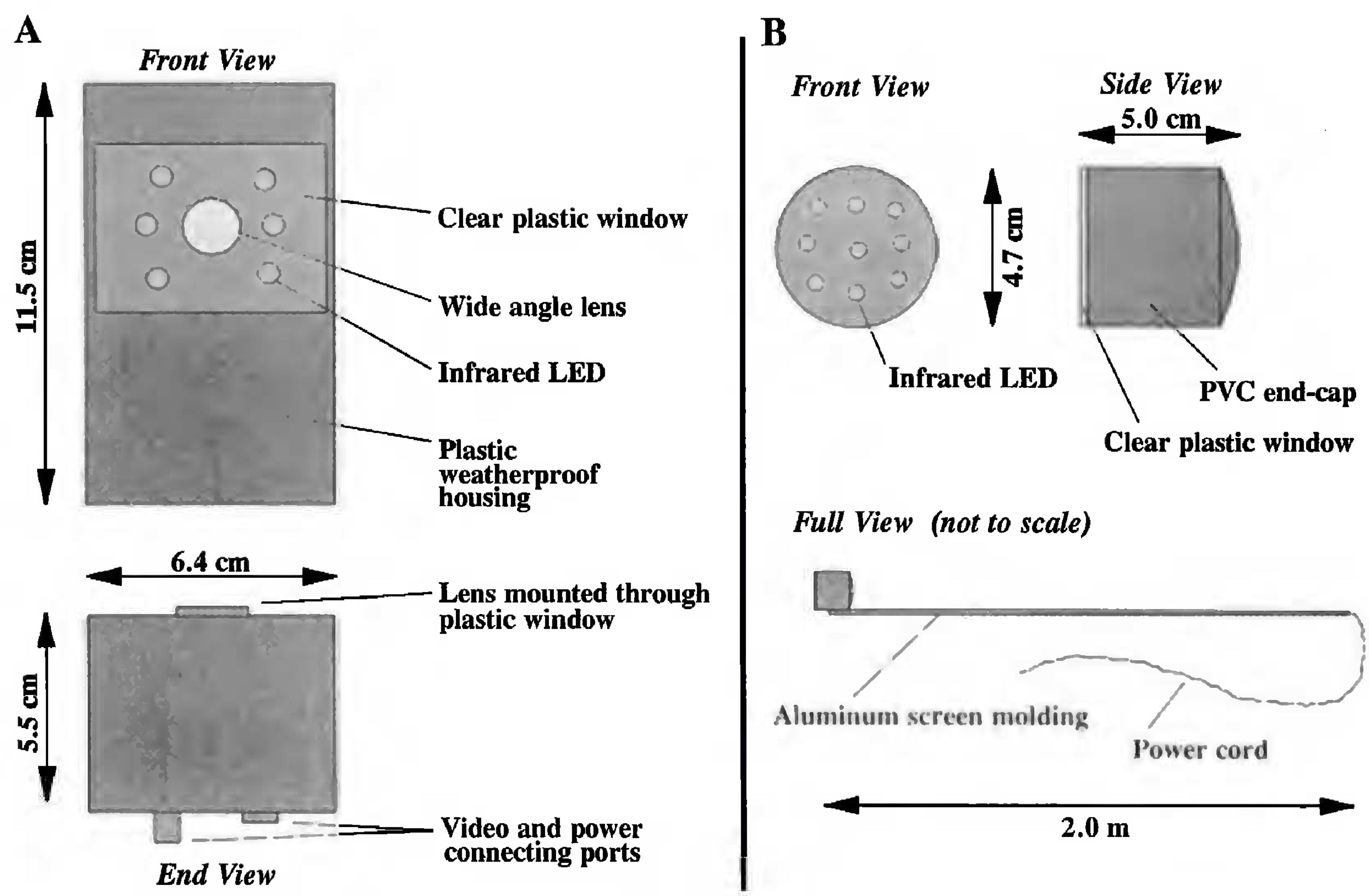

Figure 2. Schematics of (A) the black and white, circuit-board infrared video camera and (B) the supplemental, infrared light source used to extend night recording capability to ~6 m.

Table 1. Equipment and approximate costs for a night vision video surveillance system (based on 1996 prices associated with assembling 20 systems).

COMPONENT	APPROXIMATE COST ($)
Video cassette recorder	745.00
Miniature video camera	240.00
DC monitor ($110.00 per 4–5 systems)[a]	~25.00
Rechargeable batteries ($55.00, 4 per system)	220.00
Battery charger ($80.00 per 4–5 systems)[a]	~20.00
Coaxial and power cables, connectors, plugs	100.00
Protective bin	20.00
Tarpaulin and cord	30.00
Total	$1400.00

[a] Costs of DC monitors and battery chargers per system are proportionally reduced by the total number of systems deployed; we used 4 monitors (the same 10.5-cm DC monitors used to position the camera) and 4 chargers to operate 20 video systems.

cept for the lens and LED area, were painted black (Fig. 1). Two connecting ports were threaded into the protective housing for the power supply and the video signal. Cover plates were drilled to accommodate lens barrels, which when the outer portion was attached through the plate, supported the entire circuit board.

Panasonic Model AG-1070DC, industrial-grade VHS video recorders (Panasonic Corporation of America, Secaucus, NJ U.S.A.), connected to cameras via coaxial cable (RG-59), provided up to 24-hr coverage per tape. These 12-volt, DC-powered recorders were designed for law-enforcement surveillance applications. We obtained 24-hr coverage by recording approximately 5 frames per sec instead of the normal rate of 30 frames per sec. Cameras, supplemental lights, and video recorders were powered by two 12-volt, 33.0-amp-hr, Power-Sonic Model PS-12330, rechargeable batteries (Power Sonic, Redwood City, CA U.S.A.) connected in parallel because a 24-hr taping would draw a single battery below operational limits. These rugged, sealed "gel-cell" type batteries (weighing 11.3 kg each) reduced the risk of battery damage, and eliminated the potential for spillage during backpack transport. The total cost per system was about $1400.00 (Table 1). Assembly time was approximately 4 hr per camera system.

Cameras were attached to tree branches or trunks with adjustable, jointed angle-brackets and screws (Fig. 3). Cameras were mounted at the same level or slightly above nest height in the nearest practical tree, which had to be large enough to climb to nest height and also far enough

Figure 3. Branch-mounted video camera showing jointed attachment bracket, adjustable in two planes. Power and video cables are attached through connectors on the rear of the unit (not visible in this view) and anchored to the supporting branch or tree trunk.

from the nest tree so as not to disturb incubating owls. A 15-m combination power line and coaxial cable (or down line) was attached to a 10.5-cm DC-powered monitor and battery (Fig. 4), so camera placement during installation could be directed from the base of the camera tree. A minimum of two persons was required for camera placement, a climber to position the camera and a person on the ground to check the video signal and direct placement. Once the camera was positioned, the down line was taped to the tree and the system was left inoperative for up to a week. This allowed owls to habituate to camera presence prior to experiencing the visible, dull red glow of the infrared LEDs once the system was powered. Visual sensitivity of Mexican Spotted Owls to infrared light is unknown; however, Konishi (1973) has shown that Barn Owls (*Tyto alba*) are not sensitive to such light. A supplemental light source, when needed, was extended toward the nest platform, then nailed, wired, or taped in place. Its power line was spliced to the camera's with quick-connects. To make the system operational, a 60-m trunk line was attached at the base of the tree (covered by 1.2-cm diameter hose for protection against rodents), permitting the power/recording station to be placed away and out of sight from the nest tree to minimize potential disturbance to the owls. We put the recorder, two batteries, and all connectors inside a weatherproof, rubberized storage bin (61 cm × 40 cm × 24 cm; Fig. 4) concealed under a camouflaged tarpaulin. Batteries and tapes were exchanged before and after each 24-hr recording period.

RESULTS

During 10 field days between 9 April–27 May 1996, cameras were placed at 20 nest sites (1–4 sites per d depending on travel time between sites) in the Sacramento Mountains of southcentral New Mexico. Mean placement time from arrival to departure from the nest site was 42 min (range =

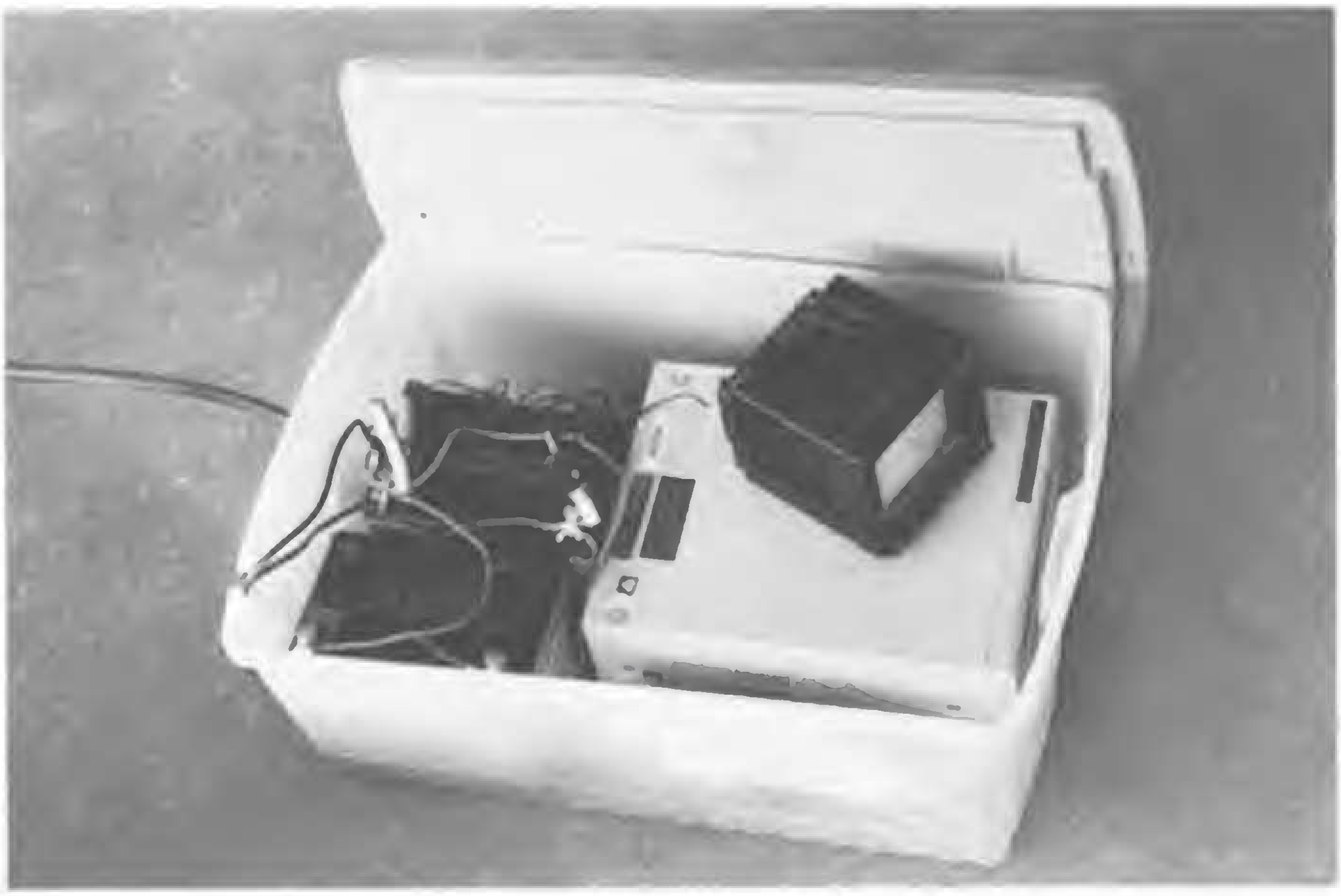

Figure 4. Weatherproof, rubberized bin housing video recorder, batteries for powering entire system, and spare tapes, with a portable monitor used temporarily to check video image reception and quality.

28–71 min). Nest height averaged 15.3 m (range = 8.0–27.0 m) in 18 Douglas firs (*Pseudotsuga menziesii*) and one white fir (*Abies concolor*). One nest tree was not measured. Cameras averaged 6.9 m from nests (range = 3.0–10.3 m). Because effective night vision was limited to approximately 6 m, we were only able to collect nocturnal information at eight nests.

We mounted 18 cameras without flushing nesting owls. Two initial mounting efforts that caused a flush were immediately aborted, with the adults returning to their nests in <5 min. We were able to mount both cameras a week later with no further response. Aside from the two flushes in 22 mounting attempts, spotted owls appeared totally unaffected by the video systems once in place. Several owls that had done so previously, even continued to perch in camera trees. There was no nest abandonment, and 18 of the 20 nests were successful. Neither nest failure was related to video camera presence (Delaney et al. 1999a).

Between 25 April–3 July 1996, our surveillance systems yielded 149 tapes and 2655 hr of taped coverage. Approximately 230 field hr were required for changing tapes and batteries or about 1.5 hr per change. In addition, over 500 office hours were required to analyze the tapes for related spotted owl behaviors such as nest attentiveness, number of prey deliveries, and number of female trips from the nest. A total of approximately 820 hr (including an additional 76 hr for equipment assembly and 14 hr for camera placement) were spent in obtaining the 2655 hr of usable video coverage, a return ratio of 3.2:1 of coverage for each hour invested.

DISCUSSION

We developed this infrared camera system to facilitate a study of helicopter noise effects on the threatened Mexican Spotted Owl (Delaney et al. 1999a). This conservative approach allowed us to observe natural behavior and spotted owl responses to experimental manipulations with minimal risk to the owls. In addition, video coverage permitted the quantification and differentiation of several subtle, nonflushing behaviors that not only facilitated and strengthened our assessment of disturbance, but also provided new insight into spotted owl nesting and foraging activities (Delany et al. 1999b).

Previous raptor responses to camera installation ranged from no apparent effect (i.e., successful fledging; Enderson et al. 1973) to extreme effects such as nest abandonment (Cain 1985, W. Bowerman pers. comm.). Responses may be affected by installation time, season, and camera placement, as well as by animal temperament and prior experience. Red-tailed Hawks (*Buteo jamaicensis*) and Northern Goshawks (*Accipiter gentilis*) have been disturbed by the mere human presence associated with research activity (Olendorff 1975, Kennedy and Stahlecker 1993). Although our cameras were carefully installed after spotted owls had initiated nesting, we strongly recommend installation prior to nesting activity and before breeding adults are present.

We would not have been able to collect the same level of detail, quality, or quantity of behavioral data through direct observation. Videotaping with the date and time on each frame provided a permanent record that could be accurately measured and reviewed for additional information. In addition, it provided uninterrupted 24-hr coverage and the capability of monitoring several nests simultaneously, thus minimizing confounding factors related to sample timing. To obtain comparable coverage via direct observation would have required 2–3 field assistants per site and tripled labor costs. Disruptive personnel shift changes and expensive night-vision equipment would also have been necessary.

Additional advantages of this camera system are that cameras are unmanned and provide 24-hr, real-time assessment of the frequency, duration, timing, and type of behaviors, as opposed to the more limited sampling regimes inherent in common forms of time-lapse or triggered photography. Infrared capability permits similar recording of nocturnal and diurnal activities without disruptive flashes. Remote placement allows observers to stay approximately 60 m from nests once cameras are installed, minimizing observer effects that might otherwise confound assessment of other human disturbances. The cameras are small, unobtrusive and quiet, and the cost per system is modest by comparison to other video systems.

We also experienced several difficulties or limitations in operating this system. Installing the 60-m cables for power and video and protecting the system from moisture, loose connections, rodent damage, and vandalism required that all cables be encased in garden hose, which had to be hidden from view and located away from any game trails to reduce possible damage. A combination of this infrared video camera system and the solar-powered transmitting system of Kristan et al. (1996) would eliminate these cumbersome cables and hoses. Night vision attenuated rapidly with distance and was clearest when cameras and supplemental lights were <6 m from nest trees. Placing cameras 1–3 m above nests in the same tree would eliminate the supplemental light and maximize night recording clarity; however, this would have to be accomplished prior to occupancy to avoid disturbance or abandonment. Typical of any video system, direct sunlight and reflection off nearby foliage distorted contrast and limited visibility into shaded areas. These factors must be considered and minimized during camera placement.

Since our application, circuit-board video cameras have become less expensive while capabilities have increased to include color, sound, as well as small, factory-built weatherproof housings. In conclusion, miniature circuit-board video systems are a reliable, relatively unobtrusive, and effective tool for monitoring behavior of raptors and other wildlife in a wide variety of applications. Based on our experience, this technique can particularly benefit research designed to assess the effects of human activities and land management practices on threatened or endangered species.

Acknowledgments

This camera system was developed as part of a study funded by the U.S. Air Force, Holloman AFB Legacy Fund. We thank P. Beier and T. Narahashi for assisting in camera development. H. Reiser, L. Pater, R. Balda and D. Patton reviewed the original manuscript.

Literature Cited

Browder, R.G., R.C. Browder and G.C. Garman. 1995. An inexpensive and automatic multiple-exposure photographic system. *J. Field Ornithol.* 66:37–43.

Cain, S.L. 1985. Nesting activity time budgets of Bald Eagles in southeast Alaska. M.S. thesis, Univ. Montana, Missoula, MT U.S.A.

Cowardin, L.M. and J.E. Ashe. 1965. An automatic camera device for measuring waterfowl use. *J. Wildl. Manage.* 29:636–640.

Danielson, W.R., R.M. Degraff and T.K. Fuller. 1996. An inexpensive compact automatic camera system for wildlife research. *J. Field Ornithol.* 67:414–421.

Delaney, D.K., T.G. Grubb, P. Beier, L.L. Pater and M.H. Reiser. 1999a. Effects of helicopter noise on Mexican Spotted Owls. *J. Wildl. Manage.* 63:60–76.

———, ——— and ———. 1999b. Activity patterns of nesting Mexican Spotted Owls. *Condor* 101: in press.

Dodge, W.E. and D.P. Snyder. 1960. An automatic camera device for recording wildlife activity. *J. Wildl. Manage.* 24:340–342.

Enderson, J.H., S.A. Temple and L.G. Swartz. 1973. Time lapse photographic records of nesting Peregrine Falcons. *Living Bird* 111:113–128.

GRUBB, T.G. 1983. Bald Eagle activity at an artificial nest structure in Arizona. *Raptor Res.* 17:114–121.

HERNANDEZ, F., D. ROLLINS AND R. CANTU. 1997. An evaluation of Trailmaster camera systems for identifying ground-nest predators. *Wildl. Soc. Bull.* 25:848–853.

JONES, L.L.C. AND M.G. RAPHAEL. 1993. Inexpensive camera systems for detecting martens, fishers, and other animals: guidelines for use and standardization. Gen. Tech. Rep. PNW-GTR 306. USDA For. Serv., Pac. Northwest Res. Sta., Portland, OR U.S.A.

KENNEDY, P.L. AND D.W. STAHLECKER. 1993. Responsiveness of nesting Northern Goshawks to taped broadcasts of three conspecific calls. *J. Raptor Res.* 27:74–75.

KONISHI, M. 1973. How the owl tracks its prey. *Am. Sci.* 61:414–424.

KRISTAN, D.M., R.T. GOLIGHTLY, JR. AND S.M. TOMKIEWICZ, JR. 1996. A solar-powered transmitting video camera for monitoring raptor nests. *Wildl. Soc. Bull.* 24:284–290.

KUCERA, T.E. AND R.H. BARRETT. 1993. The Trailmaster camera system for detecting wildlife. *Wildl. Soc. Bull.* 21:505–508.

MAJOR, R.E. 1991. Identification of nest predators by photography, dummy eggs, and adhesive tape. *Auk* 108. 190–195.

NYE, P.E. 1983. A biological and economical review of the hacking process for restoration of Bald Eagles. Pages 127–135 *in* D.M. Bird, N.R. Seymour, and J.M. Gerrard [EDS.], Biology and management of Bald Eagles and Ospreys. Harpell Press, Ste. Anne de Bellevue, Quebec, Canada.

OLENDORFF, R.R. 1975. Population status of large raptors in northeastern Colorado, 1970–1972. *Raptor Res. Rep* 3:185–205.

OSTERBERG, D.M. 1962. Activity of small mammals as recorded by a photographic device. *J. Mammal.* 43:219–229.

PATTON, D.R., V.E. SCOTT AND E.L. BOEKER. 1972. Construction of an 8-mm time-lapse camera for biological research. Res. Pap. RM-88. USDA For. Serv., Rocky Mtn. For. and Rang. Exper. Sta., Ft. Collins, CO, U.S.A.

PROUDFOOT, G.A. 1996. Miniature video-board camera used to inspect natural and artificial nest cavities. *Wildl. Soc. Bull.* 24:528–530.

Received 6 March 1998; accepted 21 July 1998